

P R O O F S
OF THE
THEORY OF THE EARTH.

ARTICLE XVI.

Of Volcano's and Earthquakes.

THE bowels of those burning mountains called *Volcano's* contain sulphur, bitumen, and other inflammable materials, the effects of which are more violent than those of thunder or of gun-powder; and they have, in all ages, astonished mankind, and desolated the earth. A volcano is an immense cannon, with an aperture often more than half a league in circumference. From this vast mouth are projected torrents of smoke and of flames, rivers of bitumen, of sulphur, and of melted metals, clouds of ashes and stones; and sometimes it ejects, to the distance of several leagues, rocks so enormous, that they could not be moved by any combination of human

man force. The conflagration is so dreadful, and the quantities of burning, calcined, melted, and vitrified substances thrown out by the mountain, are so great, that they bury whole towns and forests, cover the plains to the thickness of a hundred or two hundred feet, and sometimes form hills and mountains, which are only portions of these matters heaped up and compacted into one mass. The action of the fire and the force of the explosions are so violent, that they produce by reaction, succussions, which shake the earth, agitate the sea, overturn mountains, and destroy towns and buildings of the most solid materials.

These effects, though natural, have been regarded as prodigies; and, though we often behold, in miniature, effects similar to those of volcano's; yet grandeur, from whatever source it proceeds, has such an astonishing influence upon the imagination, that it is not surprising they should have been considered by some authors as vents to a central fire, and, by the vulgar, as mouths of hell. Astonishment produces fear, and fear is the source of superstition. The inhabitants of Iceland believe that the groanings of their volcano are the cries of the damned, and that its eruptions are occasioned by the desperation and ungovernable fury of devils and tormented spirits.

All these phenomena, however, are only the effects of fire and of smoke. In the bowels of mountains,

mountains, there are veins of sulphur, bitumen, and other inflammable substances, together with vast quantities of pyrites, which ferment when exposed to the air or moisture, and produce explosions proportioned to the quantity of inflammable matter. This is the true idea of a volcano; and it is easy for the naturalist to imitate the operation of these subterraneous fires. A mixture of sulphur, of filings of iron, and of water, buried at a certain depth below the ground, will exhibit, in miniature, all the appearances of a volcano: This mixture soon ferments to a degree of inflammation, throws off the earth and stones which cover it, and produces explosions every way similar to those of burning mountains.

The most famous volcano's in Europe are those of Mount *Ætna* in Sicily, of Mount *Hecla* in Iceland, and of Mount *Vesuvius*, near Naples in Italy. The burning of Mount *Ætna* is more ancient than the records of history. Its eruptions are extremely violent; and the quantity of matter it throws out is so enormous, that, after digging 68 feet deep, marble pavements, and other vestiges of an ancient city, have been found covered with this amazing load of ejected matter, in the same manner as the town of *Herculaneum* has been buried with the matter thrown out from Mount *Vesuvius*. New mouths, or craters, were opened in *Ætna* in the years 1650, 1669, and at other times. The smoke and flames

flames of this volcano are seen as far as Malta, a distance of 60 leagues: It sends forth a perpetual smoke, and, at particular times, it throws out, with astonishing violence, flames, lava, huge stones, and matter of every kind. An eruption of this volcano, in the year 1537, produced an earthquake over the whole island of Sicily, which lasted 12 days, and overthrew an immense number of houses and public buildings. It terminated by the bursting of a new mouth, the lava of which burnt up every thing within five leagues of the mountain. It discharged ashes so abundantly, and with such force, that they reached the coast of Italy, and incommoded vessels at great distances from the island. This volcano has, at present, two principal craters, one of which is narrower than the other. They both smoke perpetually; but flames only appear during the time of eruptions. Large stones, it is said, have been projected from them to the distance of 60,000 paces.

A violent eruption, in 1683, produced a dreadful earthquake in Sicily. It laid the whole city of *Catanea* in ruins, and destroyed more than 60,000 of its inhabitants, beside those who perished in the neighbouring towns and villages.

Hecla darts its fires through the snows and ice of a frozen climate. Its eruptions, however, are equally violent with those of *Ætna*, and other volcano's in the more southern regions. It throws out ashes, lava, pumice-stones, and

sometimes boiling water. The whole island of Iceland abounds in sulphur; but it is not habitable within less than six leagues of the volcano. The history of its most violent eruptions is recorded in a book written by *Ditbmar Blesken*.

According to historians, the burning of Mount Vesuvius began not before the seventh consulate of Titus Vespasian and Flavius Domitian. The top of the mountain then opened, and at first threw out stones and rocks. These were succeeded by flames and lava which burnt up two neighbouring cities, and volumes of smoke so thick as to darken the light of the sun. The elder Pliny, stimulated by curiosity, approached too near the mountain, and was suffocated by its sulphureous steams*. Dion Cassius relates, that this eruption was so violent, that ashes and sulphureous steams were transported as far as Rome, and across the Mediterranean into Africa and Egypt. Heraclea was one of the cities that were overwhelmed by the matter ejected from the mountain: It has lately been discovered 60 feet under the surface of the ground, which, in the course of time, had become arable, and fit for every kind of culture. The history of the discovery of Heraclea is in the hands of the public. We have only to wish, that some person, skilled in the knowledge of nature, would examine with attention the different materials which compose these 60 feet of earth, and remark their

* See Pliny the Younger's Letter to Tacitus.

situation,

situation, the alterations they have undergone, the direction they have followed, the hardness they have acquired, &c.

Naples appears to be situated upon a vault, filled with burning minerals; for Vesuvius and Solfatara seem to have subterraneous communications. When Vesuvius throws out lava, Solfatara emits flames; and, when the eruptions of the former cease, the burning of the latter is likewise extinguished. The city of Naples is nearly in the centre between them.

One of the last and most dreadful eruptions of Vesuvius happened in the year 1737*. The mountain discharged, from several mouths, immense torrents of melted matter, which spread over the fields, and terminated in the sea. M. de Montealegre, who communicated this account of it to the Academy of Sciences, observed, with horror, one of these rivers of fire, which, from its source to the sea, was about 7 miles in length, 50 or 60 paces broad, from 25 to 30 palms deep, and in the valleys 120 palms. The running matter resembled foam, or the dross which issues from a furnace†, &c.

In Asia, and particularly in the islands of the Indian ocean, volcano's are numerous. One of the most famous is Mount Albours, near Mount Taurus, about 8 leagues from Herat. The top

* This volume was published in the year 1749. Several eruptions have happened since that time. See Hamilton's History of Vesuvius.

† See l'Hist. de l'Acad. année, 1737, p. 7.

of

of this mountain sends forth a perpetual smoke; and it frequently throws out flames and burning matter, in such quantities as to cover all the adjacent plains with ashes. In the island of Ternate, there is a volcano which discharges matter similar to pumice-stones. Some voyagers allege, that this volcano is most furious during the equinoxes, because these periods are attended with certain winds which increase the inflammation of those fires that have continued to burn for ages*. The island of Ternate is not above 7 leagues round, and is only the top of a large mountain. The land rises from the coast to the middle of the island, where the volcano mounts to a height so great, that it is difficult to climb to its top. Several rills of sweet water descend from the sides of the mountain; and, when the air is calm, and the weather fine, this burning gulf is less agitated than during storms and high winds†. This is a confirmation of what I formerly remarked, and seems to prove, that the fire of volcano's proceeds not from a great depth, but from the top or higher parts of the mountain; for, if it were otherwise, high winds could not increase the violence of the flames.

There are other volcano's in the Molucca islands. In one of the islands of Mauritius, about 70 leagues from the Moluccas, there is a volcano, the effects of which are equally violent as those

* See *Voyages d'Argenson*, tom. i. p. 21.

† See *Voyage de Schouten*.

of

of the mountain at Ternate. The island of Soerba, one of the Moluccas, was formerly inhabited. In the middle of this island there is a very high mountain, with a volcano at its summit. In 1693, this volcano discharged an immense quantity of bitumen, and inflamed matter, which, after forming a burning lake, gradually extended till it covered the whole island*.

There are several volcano's in Japan, and the adjacent islands, which send out flames in the night, and smoke in the day. In the Philippine islands, there are likewise several burning mountains. One of the most remarkable, and, at the same time, the most recent volcano in the Indian islands, is that near the town of Penarucan in the island of Java. It commenced in the year 1586, and, at the first eruption, it threw out immense quantities of sulphur, bitumen, and stones. The same year, Mount Gounapi, in the island of Banda, which had been a volcano about 17 years only, opened and ejected, with a dreadful noise, rocks and matter of every kind. There are still other volcano's in India, as in Sumatra, and in the north of Asia, beyond the river Jenissea, and the river Persida: But the two last are little known.

Near Fez in Africa, there is a mountain, or rather a cavern, called *Beni-guazeval*, which constantly throws out smoke, and sometimes flame. One of the Cape de Verd islands, called

* See *Phil. Trans. Abstrid.* vol. ii. p. 391.

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the island of *Fuogo*, is nothing but a huge mountain which burns incessantly. This volcano throws out stones and ashes; and the Portuguese, who often attempted to inhabit the island, have always abandoned the project, on account of the volcano. The Peak of Teneriff, which is reckoned one of the highest mountains in the world, throws out fire, ashes, and large stones. From the top of it, rivulets of melted sulphur run down the south side across the snows. This sulphur soon condenses, and forms veins in the snow, which are distinguishable at great distances.

America, and particularly the mountains of Mexico and Peru, are much infested with volcano's: That of Arequipa is one of the most celebrated: It often produces great earthquakes, which are more frequent in Peru than in any country of the world. Next to Arequipa, the volcano's of Carrappa and Malahallo are, according to the relation of travellers, the most considerable. But there are many others in the new world of which we have no knowledge. M. Bouguer, in his voyage to Peru, published in the Memoirs of the Academy for the year 1744, mentions two volcano's, the one called *Cotopaxi*, and the other *Picbincha*. The first is at some distance from, and the other very near, the town of Quito. In the year 1742, he saw an eruption of Cotopaxi, which, at that time, burst open a new mouth in the mountain. It did no

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other damage than that of melting the snow, and producing such torrents, as, in three hours, laid the whole country, to the extent of 18 leagues, under water, and overturned every thing in their course.

Popochampeche and Popocatepec are the chief volcano's in Mexico. It was near this last that Cortes passed in his way to the city of Mexico: Some of the Spaniards ascended to the top of the mountain, where they found the crater to be about half a league in circumference. Sulphureous mountains have also been found in Guadaloupe, Tercera, and in others of the Azore islands; and, if all the mountains from which smoke or flames issue were to be considered as volcano's, their number would exceed 60. We have only mentioned those which are so formidable as, by their frequent eruptions, to prevent people from living near them.

The numerous volcano's in the Cordeliers, as I formerly remarked, produce almost perpetual earthquakes, which prevent the inhabitants from building with stone any higher than the first floor; and the upper parts of their houses, for the same reason, are constructed with rushes or very light wood. In these mountains there are also many precipices and large gulfs, the walls of which are black and burnt: They are similar to the precipice of Mount Ararat in Armenia, called the *Abyss*, and are the craters of extinguished volcano's.

VOL. I.

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A late earthquake at Lima was attended with the most dreadful effects. The town of Lima, and the port of Callao, were almost entirely swallowed up. But the mischief was still more terrible at Callao. The sea rose and covered every house in that unfortunate town, and drowned the whole inhabitants, leaving only a single tower as a monument of its devastations. Of 25 vessels which lay in the harbour, four were driven a league upon land, and the rest were swallowed up by the waves. Of Lima, which was a very large city, only 27 houses remained standing. Multitudes of people perished; and the disaster was particularly fatal to the monks and other religious, because their buildings were lofty and of more solid materials than the common houses. This calamity happened in the month of October 1746, during the night; and the succession lasted 15 minutes.

Near the port of Pisco, in Peru, there was formerly a famous city, situated on the sea-coast; but, on the 19th of October 1682, it was almost entirely destroyed by an earthquake; for the sea, having exceeded its usual limits, swept away this unfortunate city, with all its inhabitants.

By consulting historians and travellers, we shall find many accounts of earthquakes, and eruptions of volcano's, equally dreadful and destructive as those we have mentioned. Pefidonus,

donius, quoted by Strabo*, relates, that a city of Phœnicia, near Sidon, was swallowed up by an earthquake, with the neighbouring territory, and two thirds of Sidon itself; that this effect was not produced so suddenly as to prevent the inhabitants from escaping by flight; that it extended over most of Syria, and as far as the Cyclades islands and Eubœa, where the fountains of Arethusa suddenly stopped, and appeared a few days afterwards by new sources, at a considerable distance from the old; and that the earthquake continued to shake the island sometimes in one place, and sometimes in another, till the earth opened in the valley of Lepanta, and discharged a great quantity of burning matter. Pliny informs us †, that, in the reign of Tiberius, twelve cities in Asia were overturned; and he mentions ‡, in the following terms, a prodigy occasioned by a violent earthquake. 'Factum est semel (quod equidem in Etruscæ disciplinæ voluminibus inveni) ingens terrarum portentum, Lucio Marco, Sex. Julio Coss. in agro Mutinensi. Namque montes duo inter se concurrerunt, crepitu maximo adfultantes recedentesque, intor eos flamma, fumoque in coelum exeunte interdium, spectante e via Emilia magna equitum Romanorum familiarumque et viatorum multitudine. Eo concursu villæ omnes elisæ, animalia permulta, quæ intra fuerunt, exanimata sunt,' &c.

* Lib. 1.

† Lib. 1. c. 84.

‡ Lib. 2. c. 83.

St. Auguftin tells us*, that, in Lybia, 100 towns were destroyed by an earthquake. In the time of Trajan, the earth opened and devoured the city of Antioch, and a great part of the adjacent country. It was again destroyed by the fame cause during the reign of Juftinian in the year 528, and 40,000 of its inhabitants perished. It was vifited with a third earthquake in the days of St. Gregory, fixty years after the former, which destroyed no lefs than 60,000 of its inhabitants. In the reign of Saladin, anno 1182, moft of the cities of Syria and of Judea were laid wæte by the fame calamity. Earthquakes have been more frequent in Apulia and Calabria than in any other part of Europe. In the time of Pope Pius II. all the churches and palaces of Naples were thrown down, and about 30,000 lives were loft: Thofe who efaped were obliged to live in tents till houfes were built for them. In 1629, 7000 perfons perished in Apulia by earthquakes; and, in 1638, the city of Saint Euphemia was fwallowed up, and left behind it nothing but a flinking lake: At the fame time, Ragufa and Smyrna were almoft totally destroyed. In 1692, an earthquake was felt in Britain, Holland, Flanders, Germany, and France: It was moft fevere along the coafts of the fea, and near great rivers. It agitated at leaft 2600 fquare leagues, though it lafted but two minutes. The commotion was greater in

* Lib. 2. de miraculis, c. 3.

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the mountains than in the valleys*. On the 10th of July 1688, there was an earthquake at Smyrna, which began with a motion from weft to eaft. The caſtle was firſt overturned; its four walls ſeparated from each other, and funk fix feet in the ſea. This caſtle ſtood formerly on an iſthmus, which is now a real iſland, about 100 paces from the land. The eaſt and weſt walls fell; but the north and ſouth walls ſtill remain. The city, which is near 10 miles from the caſtle, was overthrown ſoon after. The earth opened in many places, attended with ſubterraneous noiſes; and five or ſix dreadful ſhocks were felt before the approach of night, the laſt of which laſted about half a minute. The ſhips in the roads were greatly agitated; the ground on which the town ſtood funk two feet; and not above a fourth of the houſes withſtood the concuſſion, and thoſe were moſtly founded on rock. From fifteen to twenty thouſand lives were loſt †. In 1695, an earthquake was felt at Bologna in Italy; and it was remarked, as a ſingular phenomenon, that the ſea was much troubled the day preceding ‡.

‘ On the 4th of May 1614, a terrible earthquake happened at Tercera, which, beſide
‘ private houſes, overturned eleven churches
‘ and nine chapels in the city of Angra; and
‘ the city of Praya was ſo much ſhaken, that

* See Ray's Diſcourſes, p. 272. † See l'Hiſt. de l'Acad. des Sciences, année 1688. ‡ Ibid. année 1696.

‘ hardly

' hardly a house was left standing: And, on the 15th of June 1628, the island of St. Michael was visited with a great earthquake. Near this island, in the open sea, there arose a new island in a place where the water was 150 fathoms deep. This island was more than a league and a half long, and above six fathoms high*.

' In the island of St. Michael, another earthquake began on the 26th of July 1691, and continued to the 12th of the following month. Tercera and Fayal were shaken next day with such violence, that they seemed to turn about. These concussions, however, were repeated there only four times: But, at St. Michael, they ceased not a moment during the space of eleven days. The islanders abandoned their houses, which every where tumbled down before their eyes, and remained the whole time in the open fields, exposed to the injuries of the weather. The whole town of Villa Franca was overturned to the foundation, and most of the inhabitants were buried under its ruins. In several places, the plains were elevated into hills, and, in others, the hills sunk down into valleys. A fountain of fresh water issued from the ground, and run for four days, and then stopped all of a sudden. The air and the sea were in such commotion, that they made a noise resembling the bellowsings of ferocious

* See Mandelstø's Voyages.

' animals,

' animals. Many people died of fear. There was not a vessel in the harbours which was not agitated in a dangerous manner; and those which lay at anchor, or were under sail, at the distance of twenty leagues, were still more severely tossed. Earthquakes are very frequent in the Azores: Twenty years before the period mentioned, a mountain in St. Michael was overturned by a dreadful earthquake*.

' In the month of September 1627, an earthquake levelled one of the two mountains of Manilla, called *Carvalos*, in the province of Cagayan. In 1645, a third part of the city was destroyed by a similar accident, and 300 persons perished in the ruins. The following year it was visited by another; and the old Indians tell us, that earthquakes are now less destructive than formerly; but they still build their houses of wood, in which they are imitated by the Spaniards.

' The number of volcano's in this island confirms the above relation; for, at certain intervals, they vomit forth flames, shake the earth, and produce all the effects ascribed by Pliny to the eruptions of Vesuvius, such as, changing the beds of rivers, making the neighbouring parts of the sea retreat, covering the places adjacent with ashes, projecting stones to great distances, and making reports louder than those of cannons†.

* Gen. Hist. of Voyages, vol. i. p. 345.
† Gen. Hist. of Voyages, vol. i. p. 129.

† See Voyage

' In 1646, an earthquake split a mountain in the island of Machian, and the explosion made a frightful noise. From the cleft issued such a quantity of flames as consumed several plantations with their inhabitants. This prodigious aperture was to be seen in the year 1685, and it probably remains to this day. It was called the *Wheel-track* of Machian, because it ran from the top to the bottom of the mountain, and, at a distance, had the appearance of a high road *.

The history of the French Academy mentions, in the following terms, the earthquakes which happened in Italy during the years 1702 and 1703. ' They began in October 1702, and continued till July 1703. The city of Norcia, with its dependencies in the ecclesiastical state, and the province of Abruzzo, suffered most; and the earthquakes were first felt in those places which are situated at the foot of the Appennines, on the south side.

' They were frequently accompanied with frightful noises in the air, and these noises were sometimes heard when the earth was at rest, and the sky serene. The most violent concussion was on the 2d of February 1703; and it was attended, especially at Rome, with a remarkable clear sky, and a great calmness in the air. At Rome it lasted half a minute, and at Aquila, the capital of Abruzzo, three

* See l'Hist. de la Conquête des Moluques, tom. iii. p. 318.

' hours,

' hours. Beside ravaging the neighbouring country, it destroyed the whole town of Aquila, and buried 5000 persons under its ruins.

' The concussions, or vibrations, of the earth, as was discovered by the motion of the lamps in the churches, were nearly from south to north.

' The earth opened in two places, and discharged, with violence, great quantities of stones, which covered a whole field, and rendered it barren. After the stones, these apertures threw up water above the elevation of the highest trees. This discharge continued a quarter of an hour, and laid the neighbouring country under water. The water was whitish, like soap-suds, and had no particular taste.

' On the top of a mountain near Sigillo, a village about 22 miles from Aquila, there was a considerable plain surrounded with rocks like a wall. The earthquake of the 2d of February converted this plain into a large unequal gulf, its greatest diameter being 25 fathoms, and its least 20. This gulf has been sounded with ropes of 300 fathoms, without reaching the bottom. At the time that the gulf was formed, flames were observed to issue out of the mountain, and afterwards a thick smoke, which continued, with some interruptions, for three days.

' At

' At Genoa they had two slight concussions
' of the 1st and 2d days of July 1703, the last
' of which was only felt by the people on the
' Mole. The sea, at the same time, sunk 6 feet
' in the port, and continued in this situation a
' quarter of an hour.

' The sulphureous water on the road between
' Rome and Tivoli sunk two feet and a half,
' both in the basin and in the canal. The springs
' and rills of water, which rendered many places
' of the plain called *Tessine* marshy, were entirely
' dried up. The depth of the water in the lake
' called *l'Enfer* was diminished three feet. In
' place of the old springs, new ones, about a mile
' distant, appeared: They are probably the same
' waters, the courses of which have been changed
' by the concussion of the earth*.

The same earthquake, which, in 1538, formed the Monti de Cinere near Puzzoli, filled the Lucrin lake with stones, earth, and ashes, and converted it into a marsh†.

' Earthquakes, also,' says Mr. Shaw, ' have
' sometimes been felt at sea. In the year 1724,
' when I was aboard the *Gazella*, an Algerine
' cruiser of 50 guns, bound to Bona to relieve
' the garrison, we felt three prodigious shocks,
' one after another, as if a weight, at each time,
' of 20 or 30 ton, had fallen from a great height
' upon the ballast. This happened when we

* See l'Hist. de l'Acad. des Sciences, année 1704.

† See Ray's Discourses, p. 12.

' were

' were five leagues to the southward of the Seven
' Capes, and could not reach ground with a line
' of 200 fathom. The captain told me, that, a
' few years before, when he was upon a cruise,
' he felt a much greater one, at the distance of
' 40 leagues to the westward of the rock of Liffon*.

Schouten, speaking of an earthquake which happened in the Moluccas, says, that the mountains were shaken, and that the vessels at anchor in 30 or 40 fathom water, were shocked, as if they had run ashore, or struck against rocks. ' We learn,' continues he, ' from daily experience, that the same happens in the ocean, where
' no bottom can be found; and that earthquakes agitate vessels, even when the sea is
' perfectly calm†.

Gentil, in his voyage round the world, has the following remarks upon earthquakes: ' 1.
' That, half an hour before the earth begins
' to shake, all animals appear to be seized with a
' panic. The horses neigh, break their halters,
' and run out of the stable; the dogs bark; the
' birds, as if stupid, fly for shelter into the
' houses; the rats and mice come out of their
' holes, &c. 2. That ships at anchor are so
' violently agitated, that all the parts of which
' they are composed seem to be torn asunder;
' their guns break loose, and their masts spring:
' These facts I should hardly have credited, if

* Shaw's Travels, p. 151. † Voyages, vol. vi. p. 103.

' they

' they had not been confirmed to me by the
' unanimous testimony of many witnesses. I
' know that the bottom of the sea is a continu-
' ation of the land; and that agitations of the
' one must be communicated to the other; but
' I could not comprehend how the different
' parts of a vessel, swimming in a fluid, should
' be affected in the same manner as if she had
' been resting on the ground. Her motion, I
' imagined, should have only resembled that
' produced by a storm; besides, in the present
' instance, the surface of the sea was smooth,
' and the whole agitation must have proceeded
' from some internal cause, because, at the time
' of the earthquake, there was no wind. 3.
' That, if the cavern of the earth which con-
' tains the subterraneous fire, runs from north to
' south, and if the buildings of a town above it
' lie in the same direction, the whole houses are
' overturned; but, if the vein or cavern runs
' across the town, the damage produced by the
' earthquake is less considerable *.

When a new volcano breaks out in countries
subject to earthquakes, they almost entirely cease,
and are seldom felt, except during great erup-
tions, as has been observed with regard to the
island of St. Christophers †.

The enormous ravages produced by earth-
quakes have induced some naturalists to imagine,

* See Voyage de M. le Géant, tom. i. p. 172.

† See Phil. Trans. abridg. vol. ii. p. 392.

that

that mountains, and all the other irregularities
on the surface of the globe, have derived their
origin from successions of the earth occasioned by
the action of subterraneous fires. This, for in-
stance, is the opinion of Mr. Ray. He believes
that all the mountains have been formed by
earthquakes, or by the explosions of volcano's,
in the same manner as Monti de Cinere in Italy,
the new island near Santorini, &c. But he has
not considered, that the small elevations formed
by earthquakes, or by the eruptions of volcano's,
are not, like all other mountains, composed of
horizontal strata; for, by digging into the Mon-
ti de Cinere, we find calcined stones, ashes, burnt
earth, iron-dross, pumice-stones, all blended
together like a heap of rubbish. Besides, if earth-
quakes and subterraneous fires had raised the
great mountains of the earth, as the Cordeliers,
Mount Taurus, the Alps, &c. the prodigious
force requisite to elevate these enormous masses
would, at the same time, have destroyed a great
part of the surface of the globe. Earthquakes
sufficient to produce such effects must have
been inconceivably violent, since the greatest
of them recorded in history have not been able
to produce a single mountain. In the reign of
Valentinian I. for instance, an earthquake was
felt over the whole known world*, and yet it
raised not a single mountain.

* Ammian. Marcellin. lib. xxvi. c. 14.

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It is capable of demonstration, however, that though an earthquake should have a force sufficient to raise the highest mountains, this force would not be able to displace the rest of the globe.

For, let it be supposed, that the chain of high mountains which traverse South America from the point of Terra Magellanica to New Granada and the Gulf of Darien, had been suddenly elevated by an earthquake, and then let us estimate the effect of this explosion. This chain of mountains is about 1700 leagues long, and, at a medium, 40 leagues broad, including the Sierras, which are lower than the Andes. This gives a surface of 68,000 square leagues. The thickness of the matter displaced by the earthquake I suppose to be one league; or, that the mean height of the mountains from their summits to the caverns, which, agreeable to this hypothesis, must support them, is one league. The force of the explosion, therefore, must have elevated, to the height of a league, a quantity of earth equal to 68,000 cubic leagues. But, action and reaction being equal, this explosion must have communicated an equal quantity of motion to the whole globe. Now, the whole globe consists of 12,310,523,801 cubic leagues. From this number take 68,000, and there remains 12,310,455,801 cubic leagues, of which the quantity of motion would be equal to that of 68,000 elevated one league. Hence it appears, that

that the force necessary to raise 68,000 cubic leagues would not be sufficient to displace the whole globe a single inch.

There is no absolute impossibility, therefore, in the supposition, that the mountains have been raised by earthquakes, were it not evident, both from their internal structure and their external figure, that they have been formed by the operation of the waters of the ocean. Their interior parts are composed of parallel strata, interspersed with sea-shells; and their external figure consists of angles every where corresponding. Is it credible that this uniform structure, and regular figure, could have been produced by sudden and desultory succussions of the earth?

But, as this notion has been embraced by some philosophers, and, as the nature and effects of earthquakes are not well understood, I shall hazard a few ideas, which may, perhaps, throw some light upon this intricate subject.

The surface of the earth has undergone many changes. At considerable depths, we find holes, caverns, subterraneous rivulets, and voids, which sometimes communicate with each other by means of chinks and fissures. There are two species of caverns: The first are those which have been formed by volcano's and the action of subterraneous fires. The action of subterraneous fire elevates, shakes, and throws off to a distance the superincumbent materials; at the same time, it splits and deranges those on each

side of it, and thus produces caverns, grottoes, and irregular hollows. But such effects are only exhibited in the neighbourhood of volcano's, and are not so frequent as the other species of caverns which are produced by the operation of water. It has already been remarked, that the different strata of the earth are all interrupted by perpendicular fissures, the origin of which shall be afterwards explained. The waters which fall upon the surface descend through those fissures, collect when their progress is prevented by a stratum of clay, and form springs and rivulets. From the nature of water, it searches for cavities or small vacuities, and has a constant tendency to force a passage, till it finds a proper vent. Wherever it goes, it carries along with it sand, gravel, and other bodies which it is capable of dividing or dissolving. In this manner, the operation of water proceeds till it forms subterraneous passages; and then it breaks out in the form of fountains, either on the surface of the earth, or in the bottom of the sea. The materials it perpetually carries off leave hollows or caverns in the bowels of the earth, which are often of great extent; and these caverns have a very different origin from those produced by volcano's or earthquakes.

Earthquakes are of two kinds: Those occasioned by the action of subterraneous fires, and by the explosions of volcano's, are only felt at small distances, previous to, or during the time

time of eruptions. When the inflammable matters in the bowels of the earth begin to ferment and to burn, the fire makes an effort to escape in every direction; and if it finds no natural vents, it forces a passage, by elevating and throwing off the incumbent earth. In this manner volcano's commence, and their effects continue in proportion to the quantity of inflammable matter they contain. When the quantity of inflamed matter is inconsiderable, it produces only an earthquake, and exhibits no marks of a volcano: The air generated by subterraneous fire may also escape through small fissures; and, in this case, likewise, it will be attended with a succussion of the earth; but no volcano will appear. But when the quantity of inflamed matter is great, and when it is confined on all sides by solid and compact bodies, an earthquake and a volcano are the necessary consequences. All these commotions, however, constitute only the first species of earthquakes, which are not felt but in the neighbourhood of the places where they happen. A violent eruption of *Ætna*, for example, will shake all the island of Sicily; but it will never extend to the distance of three or four hundred leagues. When *Vesuvius* bursts open a new mouth, it excites an earthquake in Naples and in the neighbourhood of the volcano; but these earthquakes never shake the Alps, nor do they extend to France or other countries distant from *Vesuvius*. Thus, earthquakes produced

by volcano's are limited to a small space; they are nothing but effects of the reaction of the fire, and they shake the earth in the same manner as the explosion of a powder-magazine occasions an agitation to the distance of several leagues.

But there is another species of earthquakes which are very different in their effects, and perhaps also in their cause. These earthquakes are felt at great distances, and shake a long tract of ground without the intervention either of a new volcano, or of eruptions in those which already exist. There are instances of earthquakes which have been felt at the same time in Britain, in France, in Germany, and in Hungary. These earthquakes always extend more in length than in breadth. They shake a zone or belt of earth with greater or less violence in different places; and they are generally accompanied with a hollow noise, like that of a heavy carriage rolling with rapidity.

As to the causes of this species of earthquake, it must be remarked, that the explosion of all inflammable substances, like that of gun-powder, generates a great quantity of air; that this air is highly rarefied by heat; and that its effects, from the compression it receives by being confined in the bowels of the earth, must be exceedingly violent. Let us suppose, that, at the depth of 100 or 200 fathoms, there are a vast collection of pyrites and sulphureous bodies, and that they are inflamed by the fermentation pro-

duced by the admission of water to them, or by other causes. What must be the effect? In the first place, these substances are not placed in horizontal beds, like the ancient strata, which were formed by the sediments of the waters. They are lodged, on the contrary, in the perpendicular fissures, in subterraneous caverns, and other places, to which the water has access. When inflamed, they generate a vast quantity of air, the spring of which, by being compressed within a small space, like that of a cavern, will not shake the earth immediately above, but it will search for passages in order to expand and make its escape. Caverns and channels of subterraneous rivulets and springs, are the only natural passages for this rarefied air. Into these, therefore, it will rush with impetuosity, and produce in them a furious wind, the noise of which will be heard on the surface; and it will be attended with vibrations or succussions of the ground. This subterraneous wind produced by fire will extend the whole length of the caverns or channels, and occasion a shaking, more or less violent, in proportion to its distance from the heat, and to the width or narrowness of the canals. But this motion must necessarily run in a longitudinal direction; and the shaking, of course, must be felt over a long belt of ground. This air, however, cannot produce an eruption or a volcano; because it finds sufficient room for expanding itself, and diminishing its force; or, rather, because it escapes through fissures in

the form of vapour or of wind. But, although the existence of caverns or channels for the passage of this rarefied air should be denied, it is easy to conceive, that in the very place where the explosion is made, as the earth is elevated to a considerable height, the neighbouring places must split horizontally in attempting to yield to the impulse communicated by the original motion; and, in this manner, passages may be gradually and successively opened, so as to communicate with very distant places. This explication corresponds with all the phenomena. Earthquakes are not felt at great distances at the same minute, or even the same hour. They are not accompanied with eruptions or external fire; and the noise almost constantly marks the progressive motion of the subterraneous wind. Other facts concur in establishing this theory. Blasts of wind, and vapours, sometimes of a suffocating nature, it is well known arise from mines, independent of the motion of the air produced by the current of water. It is equally well known, that winds issue from certain apertures of the earth, from caverns, abysses, and deep lakes, as Lake Boleslaw in Bohemia, which has been formerly mentioned.

When these remarks are considered, I cannot comprehend how the mountains should have originated from earthquakes, since the mineral and sulphureous bodies which occasion them are seldom to be met with but in the perpendicular

lar fissures of mountains, and in other cavities of the earth, the greatest number of which have been produced by the operation of water; since these inflammable substances produce only a momentary explosion, and violent winds which follow the channels of subterraneous waters; since the duration of earthquakes on the surface of the earth is so short, they must be occasioned by a sudden explosion, and not by a continued conflagration; and, *lastly*, since those earthquakes, which extend over large tracts of ground, never produce the smallest eminence throughout their whole course.

Earthquakes, it is true, are more frequent in the neighbourhood of volcano's, as in Sicily, and the environs of Vesuvius: But it appears, from repeated observations, that these earthquakes are very limited, and, consequently, can never form a chain of mountains.

It has sometimes been remarked, that the matters ejected from *Ætna*, after cooling for several years, and being afterwards moistened with rain, have rekindled, and thrown out flames with such violent explosions, as to occasion small earthquakes.

In 1669, during a violent eruption of *Ætna*, which began on the 11th of March, the summit of the mountain sunk considerably*; which is a proof that this volcano proceeds rather from the superior part of the mountain than from

* See Phil. Trans. Abridg. vol. ii. p. 387.

the bottom of it. Borelli, who is of the same opinion, observes, 'That the fire of a volcano proceeds neither from the centre, nor from the bottom of a mountain, but from the top; and that the inflammation never kindles but at a small depth.'

Mount Vesuvius has frequently thrown out, during eruptions, great quantities of boiling water. Mr. Ray, who imagines that the fire of volcano's comes from a very great depth, says, that this water proceeds from the sea, which communicates, by subterraneous passages, with the foot of the mountain. As a proof, he mentions the remarkable dryness of the top of Vesuvius, and the agitation of the sea during eruptions, which sometimes recedes so far as to leave the port of Naples entirely dry. But, supposing these facts to be true, they by no means prove that the fire of volcano's proceeds from a great depth; for the water they eject is certainly rain-water, which penetrates through the fissures, and collects in the cavities of the mountain. Rills and springs issue from the tops of volcano's, as well as from other high mountains; and, as the former are hollow, and have suffered more concussions than the latter, nothing can be more natural than they should collect water in their caverns, and that these waters should sometimes be ejected, along with other substances, in the time of eruptions. With regard to the motion of the sea, it arises solely from the shock com-

* Borelli de incendis Montis Aetnae.

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municated to the waters by the explosion, which makes them advance or retire according to different circumstances.

The most common substances thrown out by volcano's, are torrents of melted minerals, which overflow the environs of the mountain. These rivers of lava extend to great distances; and, in cooling, they form beds, either horizontal or inclined, in the same manner as the strata accumulated by successive sediments from water. But the former are easily distinguishable from the latter: 1. Because strata of lava are not every where equal in thickness. 2. Because they contain nothing that has not evidently been calcined, vitrified, or melted. 3. Because their extent is more limited. As there is a vast number of volcano's in Peru, and as the bottoms of most of the Cordeliers are covered with substances which have been thrown out by eruptions, it is not surprising that no sea-shells have been found there; for they must have been calcined and destroyed by the fire. But I am still persuaded, that, if the clay ground, which, according to M. Bourguet, is the ordinary earth in the valley of Quito, had been dug, shells would have been discovered there, as well as every where else, especially where the ground is not covered, like the bottoms of the mountains, with matters ejected from volcano's.

It has often been asked, Why all volcano's appear in high mountains only? I have partly

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solved

solved this question in the preceding article. But, before finishing the present subject, I shall endeavour more fully to explain myself.

The peaks or points of mountains were originally covered with earth and sand, which, after being gradually washed down to the valleys by the rains, left nothing but those bare rocks or stones called the core of mountains, which, being likewise subjected to the action of the weather, small and large fragments of them must have been occasionally loosened, and, of course, must have rolled down to the plains. The rocks at the base of the summit being fully uncovered, and having lost their original support from the sand and earth, would necessarily give way a little, and, by separating from each other, would produce small intervals. But this yielding of the lower rocks could not take place without rending those which lay above them. In this manner the core of the mountain, from the summit to the base of the lower rocks, would be split into an infinite number of perpendicular fissures of different dimensions. Through these the rains would penetrate, and carry along with them, into the bowels of the mountain, all the minerals, and other substances which they were capable of transporting or dissolving. Here pyrites, sulphur, and other combustible substances, would be produced; and, in the course of time, these bodies would accumulate in great quantities, and, by their fermentation, would give rise to explosions

sions and other effects of volcano's. Heaps of these mineral substances might likewise exist in the heart of the mountain, before the rain could penetrate so deep. In this case, as soon as the air or rain got access to them by means of the perpendicular fissures, a conflagration and volcano would instantly take place. No such phenomena can be exhibited in plains; for, as every thing there is at rest, and nothing can be displaced, it is not surprising that the existence of volcano's should be confined entirely to the mountains.

When coal-mines are opened, which are commonly found in clay-grounds, and at a great depth, the mineral substances above mentioned sometimes kindle into flames. There are examples in Scotland, Flanders, &c. of coal-mines which have continued to burn for many years. The admission of air is alone sufficient to produce this effect. But these inflammations occasion only slight explosions, and never form volcano's; because, in such places, all being plain and solid, the fire cannot be excited to such a degree as in burning mountains, which are full of caverns and cliffs, through which the air penetrates, and augments the action of the fire so forcibly, as to give rise to the terrible effects we have been describing.